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MECHANICAL CHARACTERISTICS OF CERAMIC PARTICULATE REINFORCED AL7075 METAL MATRIX COMPOSITES AND EFFECT OF AGE HARDENING ON ITS TENSILE PROPERTIES

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ABSTRACT

Aluminium materials have a massive demand in the fields of automotive, aerospace and different engineering applications in order to meet requirements of various fields. A material with sound mechanical and thermal properties is produced which is metal matrix composites in which aluminium alloy is used as a common matrix phase and different material particulates and fibers are used as a reinforcement. Experimental MMC components are being developed and find their applications in aircraft, satellites, jet engines, missiles, and space shuttle industries. In this study, ceramic materials are used as reinforcements for MMCs such as Sic, Al_2O_3, B4c and TiB_2. Al7075 is used as a base matrix material. Metal matrix composites can be fabricated using different ceramic reinforcements and in this work, stir casting method, which is a liquid metallurgy technique, is used to produce the composite materials. Four different MMCs are produced with 15% Sic, 15% Al_2O_3, 15% B4c, and 15% TiB_2. The Mechanical Characteristics such as hardness, tensile strength, and impact strength are studied for these composites. The obtained results were compared and graphically charted to characterize these materials.

KEYWORDS: Metal Matrix Composites, Al7075, Ceramic Materials & Stir Casting Method

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Original Article

INTRODUCTION

Aluminium material has less density than steel, with good corrosion resistance and mechanical properties, aluminium and aluminium alloys are being widely used in several sectors such as automotive and aerospace. Aluminium MMCs reinforced with ceramic particles have improved strength, high Young's modulus, impact strength and increased wear resistance. MMCs are becoming very popular as they demonstrate superior strength-to-weight proportion. Al alloy based MMCs are currently employed in various applications such as pistons, push rods, cylinder liners, and brake discs. Metal matrix composites consist of two materials, one is the metal matrix and the second material is reinforcement. This matrix is called as a metal alloy. In the manufacturing of these composite, the matrix and the reinforcements are combined together. The manufacturing techniques of the aluminium metal matrix composites are classified into three types, namely liquid route methods, semisolid methods, and powder metallurgy. In liquid route methods, the metal matrix composites are produced by incorporating the ceramic particulates into a molten metallic matrix and casting the material in moulds. In this

present work, stir casting technique is used. Stir casting is a liquid state method of developing composite materials in which preheated reinforcement materials are added with a molten metal by means of a stirrer, after proper mixing with the liquid composite material is then put in moulds as per required shapes.

LITERATURE REVIEW

Ravi et al [1] "conventional stir casting is an attractive processing method for producing AMCs as it is comparatively inexpensive and conducive for a broad choice of materials and processing conditions".

Pradeep R et al [2] observed the mechanical properties of Al- Si_c MMC of Aluminium alloy of grade 7075 with varying percentage of composition such as Si_C8%+Al7075, Si_C6%+Al7075, Si_C4%+Al7075, Si_C2%+ Al7075 by stir casting technique. The experimental result reveals that the grouping of a matrix material with Si_c particles, increases UTS, compressive strength, hardness and yield strength.

Muhammad Hayat Jokhio [3] investigated the Mechanical Characteristics of 7xxx aluminum matrix reinforced With Al_2O_3 using simple foundry melting technique route. He manufactured 5 different combination of matrix alloys(Cu-Zn-Mg) reinforced with Al_2O_3 particles in 4 weight percentage (2.5,5,15 and 15). 40 samples were prepared and UTS, elongation was found out using a universal testing machine. He observed that "Al_2O_3" ceramic up to 15% in weight percentage boosts the tensile strength to 297 MPa and elongation 17% in Al alloy matrix The higher tensile strength was obtained reinforced with 2.5% "Al_2O_3" particles. Aluminum composites up to 2.77% Magnesium which increases wettability, minimizes porosity and develops very solid bonding with Al_2O_3 particles.

A. Baradeswaran et.al.[4] reported,"Study on mechanical and wear properties of Al 7075/Al2O3/graphite hybrid composites". Ceramic particles along with solid lubricating materials were incorporated into an aluminium alloy matrix too

Accomplish reduction in both wear resistance and friction factor by using the liquid metallurgy route. The Al 7075/Al_2O_3/graphite hybrid composite was prepared with 5 wt.% graphite reinforcements addition and 2, 4, 6 and 8 wt.% of Al2O3 about an average particulate size of 16 μm. The hardness, tensile strength, flexural strength and compression strength of the hybrid composites are found to be increased by raising the percentage of ceramic phase.

Adeyemi Dayo Isadarea et.al.[5] find out, "Outcome of Heat Treatment on several Mechanical Properties of Al 7075" this study says there is development of micro segregations of $MgZn_2$ during the steady solidification of Al 7075 because of the solute rearrangement of Mg and Zn but this was covered up during rapid solidification. Although, the micro segregations that were produced are gradually cooled and dissolved to form a homogeneous phase during the soaking period of heat treatment operations. Because of the effect of age hardening process small particulates mgZn2 are formed in AMMCs. Due to annealing process coarse grains of $MgZn_2$ are formed in aluminium MMC. It can be implicated that quick solidification process and heat treatment reduce the formation of micro segregation and drastically improved some mechanical characteristics.

The silicon carbide reinforced MMCs possess good fracture toughness property than compared to other ceramics like Al_2O_3 and $B4_c$. This is because the Sic ceramic material is harder and it acts as a barrier to sub surface shear just like the steel counter face. [6, 7] and it is because of the particle shape difference. There is also a downside of Al-MMCs with reinforcing materials is that the reinforcement act as a subsequent-body abrasive and increase its wear rate [8, 9].

The addition of Tib_2 reinforcement increases the wear resistance of the composite and it also does the grain

refinement of aluminium alloy which improves the mechanical properties of Aluminium MMCs [10]. In addition to that, the TiB2 particles clearly improve the wear resistance property of the Al–4Cu alloy. It can be stated that the Tib2 protects because of its greater hardness and it incorporates fine iron rich debris which provides as good lubricating property to material [11].

The investigations have shown that the highest hardening possessing matrix was obtained after heating the composite material at a temperature of 560^0C for 3 hours, and quenched is done using ice water with 0^0C and ageing process is complete at a temperature of 175^0C for 7 hours. It was observed that the heat treated alloy after 7 hours of ageing possessed the greater hardness so it is the one, which provides the MMC the greater wear resistance [12-14].

From the above discussion, it can be concluded that there is less data available on the mechanical characteristics of ceramic particulates reinforced Al7075 MMCs. So, the present investigation is intended to Produce Al7075ceramic reinforced composites with all the ceramic materials containing 15% of weight of ceramic particles in each casting and to examine their density, hardness and mechanical characteristics, the castings are to be obtained with the following compositions Al7075-15% Sic, 15%, Al_2O_3, 15% $B4_C$ and 15% TiB_2.

MATERIALS AND METHODS

Aluminum alloy 7075 is light weight material with density of 2.81 gm/cm^3 it is a heat-treatable alloy with high strength. It has very good corrosion resistance and very good weld ability. Aluminum 7075 alloy has magnesium and zinc as principal alloy elements; it is used as matrix material because of it's to its good mechanical property.

Table 1: Chemical Composition of Al7075

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Weight %	0.4	0.5	1.6	0.3	2.4	0.14	5.5	0.2	90

Silicon carbide (Si_C) is a substance of carbon and silicon it is manufactured by the high temperature electrochemical reaction of sand and carbon. Sis has low density, high strength and high hardness and good elastic modulus.

Aluminium oxide (Al_2O_3) is a refractory ceramic oxide also called as alumina which is synthetically produced white in color crystalline substance. Alumina is made from bauxite, a naturally occurring ore containing variable amounts of hydrous (water-containing) aluminum oxides. Alumina has high temperature resistant good mechanical properties.[13]

Table 2: Properties of Ceramic Reinforcements

Properties	Silicon Carbide (Sic)	Aluminium Oxide (Al_2O_3)	Boron Carbide (B4c)	Titanium Diboride (TiB_2)
Density gm/cm^3	3.2	3.89	2.52	4.52
Melting point ^{o}C	2750	2072	2763	2970
Elastic Modulus (Gpa)	410	300	450	461.4
Hardness (HB500)	2800	1175	3100	3250

Boron carbide ($B4_C$) s an extremely hard material it is used in heat resistance applications because to its high melting point and thermal stability, it is also used as abrasives because of its great abrasion resistance it has greater hardness and low density and is commonly used in nuclear applications. Titanium diboride (TiB_2) Titanium diboride (TiB_2) is a known ceramic material with elevated strength and durability, it has a high melting point, hardness, strength to density ratio, and high wear resistance properties. It consists of carbon, silicon carbide, boron, molybdenum, tungsten and ceramics

such as alumina, quartz etc. [14]

Experimental Procedure

The aluminium 7075 based ceramics reinforced metal matrix composites are manufactured using stir casting technique. Four different ceramics reinforced metal matrix composite materials were produced using different ceramic particulates. The weight percentages of Al7075 and ceramics for producing MMCs are

1. 85% of Al7075 is added with 15% Si_C
2. 85% of Al7075 is added with 15% Al_2O_3
3. 85% of Al7075 is added with 15% $B4_C$
4. 85% of Al7075 is added with 15% TiB_2

The required quantities of Aluminium 7075 alloy were taken after calculating the weight percentages and the alloy was melted in the Inconel crucible of stir casting machine as shown in Figure. 1 the alloy melted completely took a liquid shape at 800^0C. Slag, which was formed on top of the molten metal was removed from the molten metal by adding hexachloro ethane (degassing) tablet, once the alloy is completed melted the preheated ceramic particulate silicon carbide (Si_C) is poured in required quantities as per weight percentages, into the Inconel crucible which contains molten Al7075 alloy, silicon carbide is preheated till 250^0C before pouring into furnace using muffle furnace as shown in Figure. 2. The stirring processes are started using mechanical stirrer, stirring is done at a speed of 300 rpm for 12 minutes. The molten metal was poured into the fabricated preheated cast iron mould (preheat temperature 400^0C) as shown in Figure. 3 and MMCs are produced in round bars as shown in Figure. 4. The same process is repeated for producing other three metal matrix composites.

Figure 1: Stir Casting Machine

Figure 2: Shows Muffle Furnace

Figure 3: Cast Iron Mold

Figure 4: Casted Metal Matrix Composite Materials

RESULTS AND DISCUSSIONS

Hardness Test

To evaluate the hardness properties of fabricated metal matrix composites Brinell hardness testing machine is used, the results of the Brinell hardness tests are obtained for both the base alloy and MMCs.

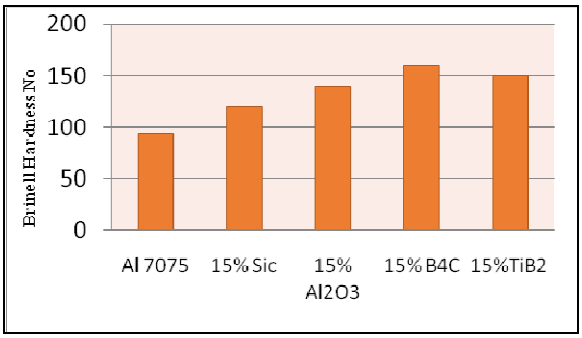

Figure 5: Hardness Tests of Composite Materials

Above Figure 5 shows that the hardness of metal matrix composites is more when compared to base Al7075alloy and it is observed that the composites reinforced with aluminium oxide (Al_2O_3), and boron carbide ($B4_C$) and Titanium diboride (TiB_2) have more hardness compared to composites reinforced with Silicon carbide (Sic).

Tensile Test

The tensile test determines the ability of a material to withstand loads before elongation the testing is conducted using Tensometer testing machine the metal matrix composites were machined as the required dimensions for the test. Ultimate tensile strength is calculated as it is the maximum stress that a material can with stand under tensile loading.

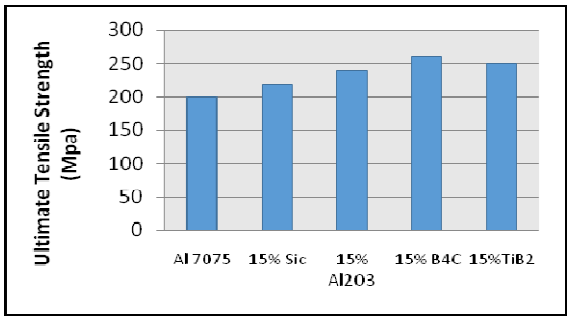

Figure 6: Ultimate Tensile Strength of Composite Materials

From Figure 6, it is clearly stated that the tensile strength increased from 195 MPa of Al7075 to 225 Mpa in Al7075+15% SiC MMC, the ultimate tensile strength of MMCs reinforced with 15%, Al2O3, 15% B4C and 15% TiB2 is more than the base Al7075 alloy and it is also seen that the UTS of composite reinforced with Boron carbide (B4c) is more that the other ceramics reinforced MMCs.

Impact Test

The impact test is conducted using Charpy impact test, it is a uniform high strain-rate test which provides the amount of energy absorbed by a material during fracture. The test specimens were machines as per the required dimensions.

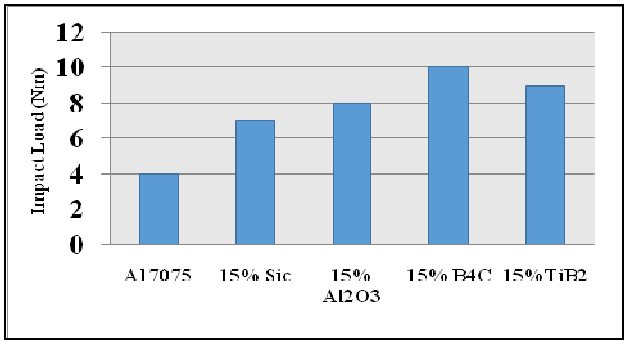

Figure 7: Impact Tests of Composite Materials

Figure 7 shows that the metal matrix composites reinforced with ceramic particulates has more impact resistance strength than the base Al7075 alloy, composite which is reinforced with ceramic material Boron carbide ($B4_C$) has more impact strength than the other composites which are reinforced with silicon carbide (Sic), and Aluminium oxide (Al_2O_3) and Titanium diboride (TiB_2).

Age Hardening

Age hardening is done by solutionizing the samples at 528^0C for 15 hours and then cooled in water after cooling the specimens were artificially aged at 167^0C for 8 hours and Effect of age hardening on the tensile strength of Al7075 Metal matrix composites reinforced with ceramics is studied.

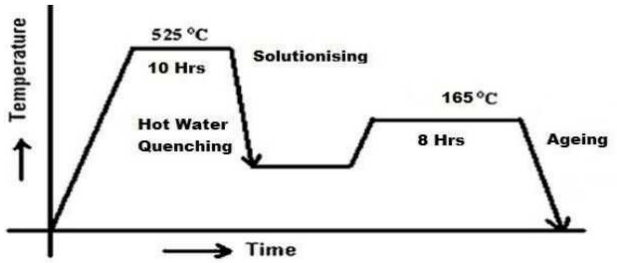

Figure 8: Diagram Representing Age Hardening Process

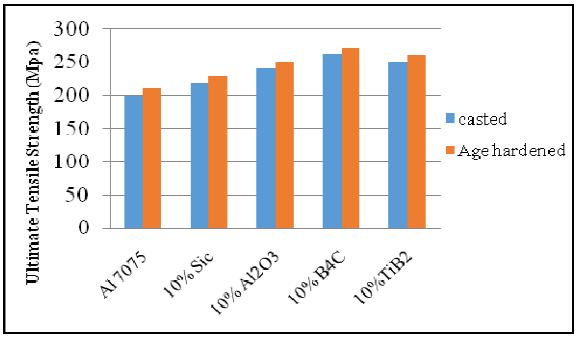

Figure 9: Comparison of Ultimate Tensile Strength of Casted MMCs and MMCs after Age Hardening

Figure 9 shows that the age hardening of metal matrix composites has increased the ultimate tensile strength of MMCs. The strain to fracture was less affected by the volume fraction of ceramic reinforcements and ageing treatment.

CONCLUSIONS

Al7075 based ceramics reinforced MMC has been successfully produced using stir casting machine using various types of ceramic particulates. The mechanical Characteristics like hardness, tensile and impact strength of MMCs are studied. Following conclusions are drawn from the above study

- A liquid metallurgy technique is used in the preparation of Al7075-15% Sic, Al7075-15%, Al_2O_3, Al7075- 15% $B4_C$ and Al7075-15% TiB2. Metal matrix composites.
- The hardness test study revealed that the hardness of ceramic reinforced metal matrix composites is more that the base Al7075 alloy. Al7075-15% TiB_2, and Al7075- 15% $B4_C$ composite materials, exhibits more hardness than other reinforced composites.
- Tensile test results show that the Al7075-15%, $B4_C$ MMC material has good ultimate tensile strength property when compared to other ceramic reinforced MMCs.
- This present study reveals that the impact strength of ceramic reinforced metal matrix composites is more than the base Al7075 alloy. High impact strength is seen in composite reinforced with Boron carbide (B4c).
- The age hardening process has increased the tensile strength of the metal matrix composites.

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